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AN EXPERIMENTAL APPROACH TO THE EFFECTS OF EXPERIENCE ON EARLY HUMAN BEHAVIOR.

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SEVERAL STUDIES ON SENSORIMOTOR FUNCTIONS IN INFANTS WERE REPORTED. DAY-TO-DAY OBSERVATIONS WERE MADE OF INSTITUTIONALIZED INFANTS IN AN ATTEMPT TO COLLECT BASELINE DATA ON ADAPTIVE ABILITIES IN CHILDREN. THE EVOLUTION OF FUNDAMENTAL SENSORIMOTOR SKILLS WAS TRACED TO PROVIDE CLUES FOR THE STUDY OF ENVIRONMENTAL EFFECTS ON THE DEVELOPMENTAL PROCESS. AFTER HAVING ACQUIRED SUFFICIENT BASELINE DATA, EXPERIMENTAL MODIFICATIONS OF REARING CONDITIONS WERE CONDUCTED TO TEST IDEAS GENERATED IN PART BY THE OBSERVATIONS THEMSELVES AND IN PART FROM GENERAL THEORETICAL VIEWS. SUCH VISUAL-MOTOR BEHAVIORS AS VISUALLY DIRECTED REACHING, VISUAL ACCOMMODATION, AND THE BLINK RESPONSE TO AN APPROACHING VISIBLE TARGET WERE DETERMINED TO CONSTITUTE BASIC TOOLS PREREQUISITE TO EARLY EXPLORATION AND INFORMATION PROCESSING. IN ADDITION, SUCH MODIFICATIONS OF THE REARING CONDITIONS AS INCREASED HANDLING, MOTILITY, AND ENRICHMENT OF VISUAL SURROUNDINGS SHOWED THAT ACQUISITIONS OF VISUAL-MOTOR SKILLS WAS "PLASTIC," OR SUBJECT TO CHANGE AS A RESULT OF THE EVENTS EXPERIENCED. (GD)

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An Experimental Approach to the Effects of Experience on Early Human Behavior

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At the end of his classic paper on the development of the sexual instinct in childhood (which was not grounded in observations of children), Freud made a plea for observational studies to test his notions. That paper was published in 1905. To this day, no one has collected the necessary information. Until Piaget's 1936 book on the ontogenesis of intelligence, no one had done any extensive day-by-day tracing of the origins of intellectual ability. Since that time, no one has extended his work at the same level of study, with the possible exception of my own studies and those of my colleagues on sensorimotor development (White, Castle, & Held, 1964; Haynes, White, & White, 1965; White, 1965). The painstaking work of Irwin and Balliet on language development is, to my knowledge, unique (except for some unpublished data of Dolores) and does not cover the first year and a half of life. Since the classic work of Bridges (1932) there have been no intensive observational studies of emotional development in normal young children. Sullivan (1953) and Erikson (1950) have constructed very provocative theories of interpersonal development but neither man has had access to extensive raw material concerning normal children during the first years of life. And so it goes. The developmental processes that must be understood are many, and the raw material out of which understanding will come is minuscule, to say nothing of weaknesses in methodology.

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Footnote - 1

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Why is it that these basic studies have not been done? Why is it that the information which would allow us to be labelled "authorities" in the truest sense of the term is not available? Why is it that the collection of careful observations which should set limits on speculation, extrapolation and armchair theorizing does not exist? Why is it that the array of recorded behavioral phenomena from which one might induce dependable theories to legitimate some of the free-floating heuristic notions currently in use is nowhere in sight? I think the reasons for this sorry state of affairs are discernible.

First of all, until recently, children less than six years of age were not easily obtainable as subjects. (For the period, 5 days to 2-1/2 years, they still are hard to come by.) More significant, however, and more easily correctable are factors inherent in the nature of our profession. Most professional students of child development can be described as part-time experimentalists intent on testing or resolving disputes between theories. We can be described as part-time because, except for an occasional post-doctoral research fellow, the majority of us hold academic positions. Teaching, administrative chores and professional duties not only reduce the time available for research, but also restrict it to certain hours of the day. We are experimentalists because otherwise we would not be taken very seriously by our colleagues. Clinical reports, anecdotal tidbits and sweeping theoretical statements, though not uncommon, are looked upon with less and less enthusiasm by serious workers in this field. Further, non-experimental output is less likely to get published in American Psychological Association journals. Finally, we may be said to be preoccupied with theory. Most published articles presuppose or state some theoretical position and contain one or more

hypotheses which have been deduced from it. Again, such a format is the one most likely to succeed. While understandable, this state of affairs does not, in my opinion, bode well for the field.

Who have been the outstanding men in child development? I count only two, Freud and Piaget. Is it a coincidence that both came from the biological sciences? I don't think so. Neither do I think it coincidental that the work of both men rests on enormous amounts of non-experimental unbiased observation. Both Freud and Piaget collected vast quantities of information from subjects under naturalistic or near-naturalistic conditions. Their observations were, of course, guided by theories, but the gap between theory and behavior was very great. The work of these men has a quality of authenticity which suggests that replications will generally be successful, as indeed they have been. The same thing is true about the work of other people who have gathered first-rate observational evidence. When Wolff published his 1959 paper on observations of the human neonate, it proved immediately useful and replicable. And, moving to a related field, would anyone doubt the reliability of the descriptions of other species by Lorenz (1952)?

Work of this kind is rare and expensive. The book, Personality in Young Children by Lois Murphy (1956) describes personality development in one child over a three-year period. Several people made major investments of their time to produce this unique chronicle of normal child development. But it is a gold mine for students of personality. Nowhere else in the literature can one get so close to skillfully collected raw material.

These kinds of studies are powerful. I think the major reason they are powerful is because we are a field hungry for facts, or, as Wright

put it, a field without a "natural history" (1960). Wright doesn't make as much of this point as I think he should. ~~We are constantly hungry for~~ We are constantly searching for some material to plug our theories into. Perhaps the most striking example of this condition is developmental psycholinguistics, where the only raw material sufficiently detailed for the purpose of supporting sophisticated theory is that of Roger Brown and Ursula Bellugi (1964). Brown and Bellugi have made the investment (extensive first-rate observations) with three children over many months. This is the extent of the direct detailed evidence we have. Yet note the importance of the problem and consider the amount of theorising that is being generated on the acquisition of language.

It seems to me that child development is overladen with theories and concepts, and, worst of all, these heuristic devices have all (with one exception) been imported from foreign soil. Psychoanalysis came from studies of middle-class neurotic Viennese women; conservation theory from studies of molluscs; learning theory from dogs, mice, cats and monkeys; Gestalt theory from human adults, chimps and mice; instinct theory from birds, fish and insects. The lone exception is the concept of "reciprocal interweaving" from Carroll. And here is a clue to our dilemma. The data of the behavioral sciences involve inter-relations among groups of laws such as those of physics, chemistry, electricity and experience. The degree of complexity involved is apparently far beyond that dealt with by the older sciences. Yet we devote next to none of our energy to familiarising ourselves with our subject matter, and we use second-hand theories. In his recent delightful book, Schaller (1964) decries the fact that so few studies have been done of the gorilla, man's closest kin among other animals. Ironically enough, we don't really know much

more about homo sapiens, (despite the fact that young humans are all around us.)

It is often remarked that a comprehensive developmental theory is much needed. Actually I believe this to be the case, but I do not think we have the raw material out of which to construct a developmental theory of consequence at this time. I think we had better invest most of our resources in sharpening our observational tools and collecting twenty years of solid natural history first. OK BW

Sensorimotor Function in Infants

My own area of interest is the role of experience in the ontogenesis of adaptive abilities in man. By adaptive abilities I mean those capacities or skills with which man copes with life. I am particularly interested in the constellation of mental skills we call intelligence or problem-solving abilities. Like Skinner, I see the domain of the psychologist as the manipulation of experience through environmental modifications. Further, I feel professionally obliged to work on the problem of how to structure a child's world so that experience has the maximum positive effect on growth and development.

Our first attempt at studying sensorimotor function in infants was quite conventional. Held et. al. (1958) had used an ingenious apparatus to measure the accuracy of hand-eye coordination in human adults. That device utilized a mirror to reflect a virtual image of the target to a writing surface while simultaneously precluding sight of the hand. The result was that the subject marked the position of the target without seeing his own hand. In this way visual correction for error was not possible. Performance was thus a clear indication of the state of hand-eye coordination. We attempted to construct such a device for young in-

faults. We hoped to be able to get a dependable measure of reaching accuracy to assess the effect of modifications of rearing conditions. The rearing conditions were to be designed to test "reafference" theory as advocated by Held et. al. (1961, 1963).

We spent a year building an elaborate apparatus with which we finally gathered some interesting data. However, we found that infants did very little reaching in the apparatus until they were some 7 or 8 months old, in spite of our best efforts. We also found that we could easily elicit repeated responses from infants 3, 4 and 5 months of age in the warm-up period before we put them in the apparatus. We therefore temporarily shelved our gadgetry and started paying more attention to our subjects.

From that point (sometime in 1960) until now, we have pursued a different line of attack. We have been following a three-part plan. Parts (a) and (b) consist of tracing the evolution of fundamental sensori-motor abilities from birth on, and simultaneously looking for clues as to how the environment affects each developmental process. The third portion of the work consists of experimental modifications of rearing conditions to test the ideas generated partly in the observational studies and partly from general theoretical views such as those of Piaget and Held.

Subjects

Our subjects are infants born and reared in an institution because of inadequate family conditions. These infants are selected from a larger group after detailed evaluation of their medical histories[2] and those of their mothers, along with relevant data on other family members whenever possible. Only physically normal infants are used in out studies. Reports based on studies of institutionally-reared infants generally include a statement acknowledging atypical conditions. In addition, such a group of infants congenitally may constitute a non-

Footnote -- 2

[2]Infants' daily records ~~were~~ ARE screened under the supervision of Drs. P. Wolff and L. Crowell for signs of abnormality using standard medical criteria. Mothers' records ~~were~~ ARE examined for possible genetic pathology and serious complications during pregnancy or delivery.

representative sample. On the other hand, two factors make a group of such infants unusually suitable for experimental research. First, rearing conditions are virtually identical for each infant, in marked contrast to the highly variable conditions for subjects reared in their own homes. Second, it is possible to systematically change rearing conditions in the institutional setting and to maintain continuous surveillance over their administration.

Figure 1 illustrates the typical nursery ward facility for infants between the ages of 1 and 4 months. Clearly the world of these infants is bland and uniform.

Insert Figures 1 and 2 about here

Procedure

The invariant core of our procedure involves weekly three-hour continuous observations of each of our subjects. Infants are observed as they lie in their cribs in the wardrooms. The regular hospital routine is not interfered with except that every child, experimental or control, has his diaper changed, if necessary, every half hour if he is awake. The quality and quantity of visual-motor activity is recorded during this period. Details of this procedure have been reported elsewhere (White & Castle, 1964).

Observational Data on Visual Attention

Briefly, visual attention is defined as the state in which the infant's eyes are more than half open, their direction of gaze shifting within 30 seconds. Figure 2 illustrates the development of this activity from birth through 4 months of age. Each point represents the average of two scores taken during successive two-week periods. It is interesting to note the correspondence between rather dramatic changes in the visible environment and the shape of this curve. For example, the sharp increase

in slope at about 2 months of age occurs at about the same time as the onset of sustained hand regard. For the next six weeks or so, the child spends much of his waking time observing his fist and finger movements. The next major change in the visible environment occurred for those infants between 3-1/2 and 4 months (see vertical line on Figure 2). They were transferred to large open-sided cribs. The combination of greater trunk motility, enabling them to turn from side to side, and the more accessible visual surround gave them access to a much more variable stimulus array. At about this time, the slope of the curve again shows a sharp increase.

Perhaps the greatest return from this time-consuming procedure is a level of knowledge about individual subjects and group behavior at various ages which one rarely attains in conventional experimental work. Of central importance is the insight gained into idiosyncratic state patterns in subjects. Escalona (1962) and Wolff (1959) have both emphasized the importance of the state variable in infant work. I would not only endorse their views, but also suggest that until such time as we have highly refined objective measures of state, there is no substitute for getting to know infant subjects well. It may appear that I am exaggerating the importance of this point, but considering the difficulty in controlling error variance in infant research, the investigator ought to take advantage of whatever leverage he can exert. The second dividend from the practice of weekly watches is a generalized understanding or "feel" for different levels of functioning during the first half year of life. Any person who has worked with large numbers of infants during that age span knows that development proceeds very rapidly. Newborns, for example, are strikingly different from six-month or even four-month

old infants. Such a fact means that the practice of lumping data gathered on infants who vary in age by more than a few weeks is a poor one.

One important revelation for me which resulted from these weekly observations was that, contrary to my academically-bred expectations, infants weren't really very "oral" during the first months of life. In fact, between 2 and 6 months, a far more appropriate description would be that they are "visual-prehensory" creatures. We watched subject after subject spend dozens of hours watching first his fists, then his fingers and then the interactions between hands and fingers. Thumb-sucking and mouthing were rarely observed except for brief periods when the infant was either noticeably upset or unusually hungry.

But "naturalistic" observations have their limits. One cannot simply wait for the repeated occurrence of the behaviors of focal interest nor can one afford to leave uncontrolled the circumstances under which they occur. Therefore, guided by what we were seeing in the nursery, and also by various suggestions from the literature, we constructed, and are still constructing, standardized test situations. These situations are designed to elicit samples of abilities (usually visual-motor) at various points in their evolution. Aside from the three-hour watches which constitute the situation in which we assess the sheer amount of visual-motor behavior engaged in, we have tested for visually-directed reaching (White, Castle, & Held, 1964), visual accommodation (Haynes, White, & HELD White, 1965), blinking to a rapidly approaching object (White, 1965) and general development (using the Gesell SCHEDULES procedures).

Each of these samples of behavior has been chosen because of its fundamental bearing on the infant's overall capacity to perform common-

motor interactions with his environment. With the exception of the Gesell test, each of these behaviors, and others we are currently working on, constitute basic "tools" normally prerequisite to early explorations and information processing. They are complicated sensori-motor responses deliberately not dissected but treated globally in order to preserve their psychological meaning. Analytical studies such as the analysis of monocularly-mediated responses are not being pursued at this time, because we feel that narrowing of the focus of this work would be strategically premature. In the realm of visual-motor responses, other behaviors, such as hand regard and visual convergence, are being studied currently. We hope to study the major visual-motor abilities and their prerequisites and then go on to other modalities, the tactual mode being next.

Visually-directed Reaching

To the best of our knowledge, no previous investigator, aside from Piaget (1952), has studied in detail the acquisition of visually-directed reaching. However, Piaget was not centrally concerned with prehension and he observed only three subjects. Consequently, his data, though very provocative, are primarily of suggestive value. Figure 3 depicts the results of our study: a ten-step analysis culminating in visually-directed reaching just prior to five months of age (White, Castle, & Held, 1964). Moreover, by the time swiping behavior occurs, at about 2 months, the infant is prepared to focus his eyes on targets (Figure 4). Convergence of the eyes as checked by clinical procedures was also found to be effective at this time. The range of accommodation increases rapidly during the period when hand regard makes its appearance.

Hands to the midline and clasp is characteristic of the bilateral behavior seen during the fourth month of life as the influence of the

Insert Figure 3 about here

tonic neck reflex drops out. Torso-orienting reflects the child's growing capacities for gross motor action. What we have called a "Piaget-type" reach was described by Piaget as a raising of one hand to the vicinity of the object, followed by alternation of glance between hand and object, a narrowing of the gap between them, and then contact. This response and the "top level" reach reflect a return to unilateral function in the fifth month of life.

We were particularly interested in the fact that striking at objects appeared as early as the beginning of the third month, whereas top level reaching did not appear until almost three months later. Was this delay inevitable, or a consequence of rearing conditions? Another point of interest was the question of the onset of sustained hand regard. Does this behavior presuppose a certain minimum level of acuity? What role did convergence of the eyes play here?

Visual Accommodation

Visual accommodation is the activity by which the image of a target is focused on the retina of the eye. This adjustment is largely accomplished by contraction or relaxation of the ciliary muscle which in turn changes the shape of the crystalline lens. Prior to the present research (Haynes, White, & HELD, 1965), there has been no systematic study of the development of visual accommodation in human infants. We have used the technique of dynamic retinoscopy for this purpose. The test procedure is designed to measure the subject's accommodative ability under conditions more relevant to normal function than those used in traditional ophthalmological examinations. The subject's accommodation to targets placed at several measured distances is tested objectively with eyes free of drugs. (Routine ophthalmological examinations employ

cycloplegic drugs.) He is then tested for his capacity to track the target as it is moved toward and away from his eyes. Together with Dr. Harold Haynes of Pacific University, we performed 111 dynamic retinoscopy examinations on 25 of our infants. The results of this study are shown in Figure 4.

Insert Figure 4 about here

Perfect adjustment to changing target distance would be represented by a slope of 0.00 on the graphs (Figure 4). Complete absence of accommodative change would be indicated by a slope of +1.00. Prior to one month of age, the infant's accommodative response does not adjust to change in target distance. The system appears to be locked at one focal distance whose median value for the group is 7-1/2 inches. This is indicated by a slope value for the group of +1.00. Occasionally, infants of this age did not remain alert long enough to allow complete calibration of their responses. In these few instances, the magnitude of error was estimated (see caption of Figure 4). Flexibility of response begins at about the middle of the second month. Performance comparable to that of the normal adult is attained by the fourth month, as shown by a median slope value of +0.03.

In addition to the above measurements, eleven infants were retinoscoped while asleep in the nursery. In all eleven cases, the accommodative system was found totally relaxed. Infants less than one week of age occasionally exhibited slow changes in accommodation, but they were in no way related to distance of the target. Older infants, when drowsy, exhibited a gradual drift of accommodation towards optical infinity, suggesting that drifting seen in the first week of life is a function of level of drowsiness.

The Blink Response to an Approaching Visible Target

In Riesen's (1958) studies, young chimps deprived of experience with patterned light failed to develop the blink response to approaching visible targets. In Held and Hein's (1963) study of kittens deprived of self-induced motion in the presence of patterned light, similar deficits developed with respect to this response. The literature on human infants contains several references to the palpebral response but in each case the test circumstances combined the visual stimulus with touch or changes in air pressure as the target approached the face.

We have performed a pilot study on ten infants ranging in age from 1 month to 5 months of age. A six-inch bulls eye target with 1/4 inch red and white concentric rings was mounted in a frame directly over the head of the supine infant. A plexiglass shield was placed 2 inches above the infant to preclude changes in air pressure as the target was dropped toward the subject. The range of target drop was from 2-5/8 to 12-1/2 inches. Brightness changes were not totally prevented but the sources of light were arranged to minimize such effects. Recording procedures were also crude in this preliminary effort. One observer released the target and reported the magnitude and latency of response, the other recorded the data. The results were remarkably consistent.

The median age for the onset of blinking was 2 months. The maximum target drop (12 1/2 in.) had to be used to elicit the response at this age and it was often slow and incomplete. By 3 1/2 months, the group exhibited very rapid and completed blinks and even occasional startles in at least 7 out of 10 trials. A target drop of but 2 5/8 in. was sufficient to elicit these responses.

In the process of collecting baseline data, we have simultaneously been on the alert for aspects of rearing conditions which may either impede or enhance development. For example, guided generally by theories such as Piaget's (1952) and Hebb's (1961, 1963), we have looked for ways in which mobility is affected by rearing routines and physical conditions. We further have studied the colors and forms available to our infants. After many hundreds of hours of tests and observations, we have been able to design experimental curricula for young infants. In a series of enrichment studies (White, 1965; White & Castle, 1964), each built upon the lessons of the previous one, we have managed to demonstrate that the acquisition of visual-motor abilities is plastic.

First Modification of Rearing Conditions--The Handling Study

Many recent studies have reported the remarkable effects of postnatal handling on the subsequent development of laboratory-reared animals (Denenberg & Karas, 1959; Levine, 1957; Meier, 1961). Mice, kittens and dogs given small amounts of extra handling grew up to be "better" animals as measured by a wide variety of tests. They were superior in many physical and adaptive respects. Recent surveys of maternal deprivation studies by Harrow (1961) and Casler (1961) suggest that early handling appears necessary for adequate human development. Sylvia Brody in her book, Patterns of Mothering (1951), noted that infants who received moderate handling were consistently more visually attentive than those receiving minimal handling. Would extra handling of our subjects, who normally receive minimal amounts, result in accelerated visual-motor development?

From day 6 through day 36, nurses administered 20 minutes of extra handling each day to each infant ($N = 10$). Measures of overall develop-

ment, physical growth, general health, the development of reaching, and visual attention were taken regularly between days 37 and 152 (White & Castle, 1964).

Insert Figure 5 about here

No changes were found in any developmental process except the growth of visual attention. The handled group was significantly more visually attentive than controls (Figure 5). Note that the shapes of the curves are quite similar. Sustained hand regard appeared about 1 week later in the handled group (day 58) than in controls (day 50). Upon relocation in large open-sided cribs the handled group, like the control group, exhibited a sharp increase in visual attentiveness.

Aside from the relationship between handling and visual attentiveness, the major finding of this study was that an innocuous environmental modification resulted in a significant alteration in the rate of growth of visual exploratory behavior. No evidence for comparable plasticity in other visual-motor developments was found following the extra handling. It is possible that further exploration of the effects of early handling would produce still greater increases in visual exploratory behavior.

Second Modification of Rearing Conditions - The Massive Enrichment Study

Several recent studies seem to indicate that visual-motor performance depends to a significant extent on experience of some kind for its development. Riesen's (1958) work demonstrated that chimpanzees require exposure to patterned visual stimulation for normal visual-motor development. His later studies have suggested that movement within a patterned environment is also required for adequate development (Riesen, 1958). Held and his collaborators (Held & Bossom, 1961; Held, 1961; Mikaelian, & Held, 1964) have repeatedly demonstrated the importance of self-induced

movement in dependably structured environments for adaptation to rearranged sensory inputs in human adults. More recently, their study of neonatal kittens cleared the applicability of these findings to developmental processes (HELD & HEIN 1963). The results of this study indicated that movement per se in the presence of a dependable surround was insufficient for normal visual-motor development. Kittens whose movements were externally-produced rather than self-induced did not develop normally. Self-induced movement in a dependable surround was found necessary for adequate development as well as maintenance of stable visual-motor behavior.

Our subjects are normally reared under conditions which are obviously less than optimal with respect to the types of experience discussed above. Motility is limited by soft mattresses with depressions in them as well as the supine posture in which these infants are kept. The visual surround is poorly figured. Consequently, according to our hypothesis, heightened motility in an enriched surround should produce accelerated visual-motor development.

As a first test an enriched environmental context of a group of 19 infants in as many respects as feasible:

a. Increased tactual-vestibular stimulation. Each infant received 20 minutes of extra handling each day from day 6 through day 36.

b. Increased motility. Infants were placed in the prone posture for 15 minutes after the 6 a.m., 10 a.m., and 2 p.m. feeding each day from day 37 through day 124. At these times, the crib liners were removed, making the wall activities visible to the child. Movements of the head and trunk in the presence of a figured visual surround resulted from the normal tendency of infants to raise their heads under such circumstances.

The crib mattresses were flattened, thereby facilitating head, arm, and trunk motility.

c. Enriched visual surround. A special stabile featuring highly contrasting colors and numerous forms against a dull white background was suspended over these infants from day 37 through day 124 (see Figure 6). In addition, printed multi-colored sheets and bumpers were substituted for the standard flat white ones. These changes were designed to produce heightened visual interest and increased viewing of hand movements because of the normal tendency of infants to swipe at visible objects nearby.

Insert Figure 6 about here

Weekly measures of prehensory responses and visual attention were made. The rates of development of spontaneous behaviors related to visual-motor function such as hand regard, hands touching at the midline, mutual fingering, and torso turning were assessed from the records of the 3 hour observation periods. Performance on the Gesell tests was recorded at bi-weekly intervals to determine general developmental progress. Also, records of rate of weight gain and general health were kept.

Results

Hand Regard and Swiping. Hand regard as such was much less frequently shown by this group as compared with controls. Instead the hands were generally first observed as they contacted portions of the experimental stabile. We called this pattern "monitored stabile play" and considered it together with "monitored bumper play" as forms of hand regard. By these criteria the onset of hand regard was delayed for some two weeks in our experimental group (U.S.; Mann-Whitney U Test). The onset of swiping was also set back, but only by some 5 days (U.S.; Mann-Whitney U Test). Figure 7 illustrates the responses to the test object leading

Insert Figures 7 and 8 about here

to reaching for this group.

Prehension. The median age for the first appearance of top level reaching was 98 days for the experimental group, an advance of some 45 days ($p < .001$; Mann-Whitney U Test). Some of the types of preliminary responses reported for our control group did not occur prior to the onset of top-level reaching.

Visual Attention. The course of development of visual attention was also altered dramatically in our experimental group as illustrated by Figure 3. Concurrent with the unexpected delay in the onset of hand regard was a marked decrease in visual exploratory behavior for the first portion of the test periods. On the other hand, once the group began to engage in prehensory contacts with the stabile and figured bumpers, visual attention increased sharply.

Clearly the results of this study demonstrated the plasticity of several visual-motor developments. That the onset of hand regard is in part a function of environmental factors is not a novel notion. Hand regard is an 04th day behavior on the Gesell scale. Our control infants, with virtually nothing else to view, discovered their hands at less than 60 days of age. Piaget (1952) noted that the onset of this behavior varied by as much as three months among his own children as a function of differing environmental circumstances. Therefore, the fact that infants provided with enriched surrounds were late in discovering their hands as compared to controls was not totally unexpected.

We were surprised that the group exhibited less visual attention during the first five weeks in the enriched visible surround. In fact, not only did they tend to ignore the stabile and bumpers, but it is our impression that they engaged in much more crying than the control group

during the same period. Starting at about 72 days of age the group as a whole began to engage in a great deal of stabile play. As we had suspected, the rattles were repeatedly swiped-at, thereby producing far more monitored hand and arm movements than would normally have occurred. Subsequently, in less than one month, the integration of the grasp with approach movements had been completed. Control infants had required almost 3 months for this transition.

Earlier we had noted that the course of development of visual exploratory behavior seemed to reflect the availability of interesting things to look at. We had seen that in control and handled groups the slope of the curve of visual attention increased sharply when the hands were discovered and then decreased during the next six weeks. In this experimental group it appears that for about a month starting at day 37, the enrichment was naturally ineffective and perhaps even unpleasant. However, once positive responses to the surround began to occur visual attention increased sharply in striking contrast to the previous groups. The dip seen at 3 1/2 months in both previous groups disappeared.

Further Modifications of the Environment

Until day 37 procedures for the third study were the same as in second study, but instead of enrichment by prone placement and the stabile and printed sheets and bumpers, there was only one modification from day 37 until day 68. Two pacifiers were mounted on the crib rails. These devices were made to stand out visually by appending to them a red and white pattern against a flat white background (Figure 9). The objects were 6 to 7 inches away from the corneal surfaces of the infant's eyes. They were positioned so as to elicit maximum attention from a 6

Insert Figure 9 about here

to 10 week old infant. The normal tendency of such infants is to accommodate at about 8 to 10 inches. It was assumed that the pacifiers might have the effect of orienting the infant towards the discovery of his own hands. It was further assumed that these objects might provide appropriate anchor points in space intermediate between the locus of spontaneous fixation and the ordinary path of motion of the hand extended in the tonic neck reflex posture.

At 63 days the infant was then placed in a crib with a stabile similar to the one used in the previous study until he was 124 days of age. We hypothesized that these infants would be more consistently precocious in the attainment of visually-directed reaching. We also expected consistently higher visual attention from this group.

Results

Hand Regard and Sniping. In the control group the onset of sustained hand regard occurred at day 50. Infants in the handling study were slightly behind (day 58). Infants in the second study were even later in this respect (day 66) supporting the idea that the discovery of the hands is, in part, a function of the availability of interesting visible objects. The modified enrichment of this last study seemed more appropriate for the infant during the second month of life; infants exhibited sustained hand regard at day 45. It should be noted that control infants reared in bland surroundings are about as advanced in this regard. The onset of sniping responses followed the same general pattern with infants in the third study exhibiting this behavior earlier than all other groups (day 53; see Figure 10).

Prehension. Apparently, the modified or pixed enrichment of the last study was the most successful match of external circumstances to

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Insert Figures 10 and 11 about here

internally developing structures. This is indicated by the acquisition of top level reaching at less than 3 months (day 89 - significantly earlier than controls at $p < .001$; Mann-Whitney U Test).

Visual Attention. Figure 11 shows visual attention data for the subjects of the several studies. The depression of visual interest shown by the infants in the second study from (day 37) to (day 74) has been eliminated. Curiously, although the last group was more consistently attentive than the others, the reduction of such behavior at 3 1/2 months appeared as it had in the first two groups. It would appear that some uncontrolled variable is interacting with our various attempts at modifying the function.

The studies reported above demonstrate that aspects of early visual-motor development are remarkably plastic. As yet we know neither the limits of this plasticity nor the range of visual-motor functions that fall within this classification. At the very least, the onset of hand regard and visually-directed reaching and the growth of visual attentiveness are significantly affected by environmental modification. Infants subject to the second and third sets of modifications in rearing developed top level reaching in approximately 60% of the time required by the control group, a result very much in line with the theory that self-initiated movement with its visual consequences is crucial for visual-motor development. Whether or not visual accommodation, convergence, pursuit, and blinking to an approaching target share this plasticity remains to be seen.

Though our work constitutes only a beginning effort at solving an enormously complicated problem, and though we cannot say whether or not accelerated development has definite long-term significance, I think the

implications of our findings are potentially of great importance. Both Hunt (1961) and I (White, in press) have argued that the question of the limits of human potential can only be answered by continuous matching of optimal environments to emerging abilities. This means that at each stage of life, starting at least as far back as birth, we must ultimately be able to assess the various abilities of a particular CHILD, and then tailor-make rearing conditions to suit them. Subsequently as his abilities become manifold and more complex we must keep pace by continually modifying his environmental circumstances (insofar as this is possible) to maximize assimilation, using Piaget's term. Such an interlocking arrangement must be sustained throughout the developmental years. Only in this way may the maximally positive effects of experience be assessed for a single human being.

I do not pretend that this is a task that developmental psychology is adequately prepared for. I do claim that, though crudely defined, and not necessarily attainable, it is the primary task for the field.

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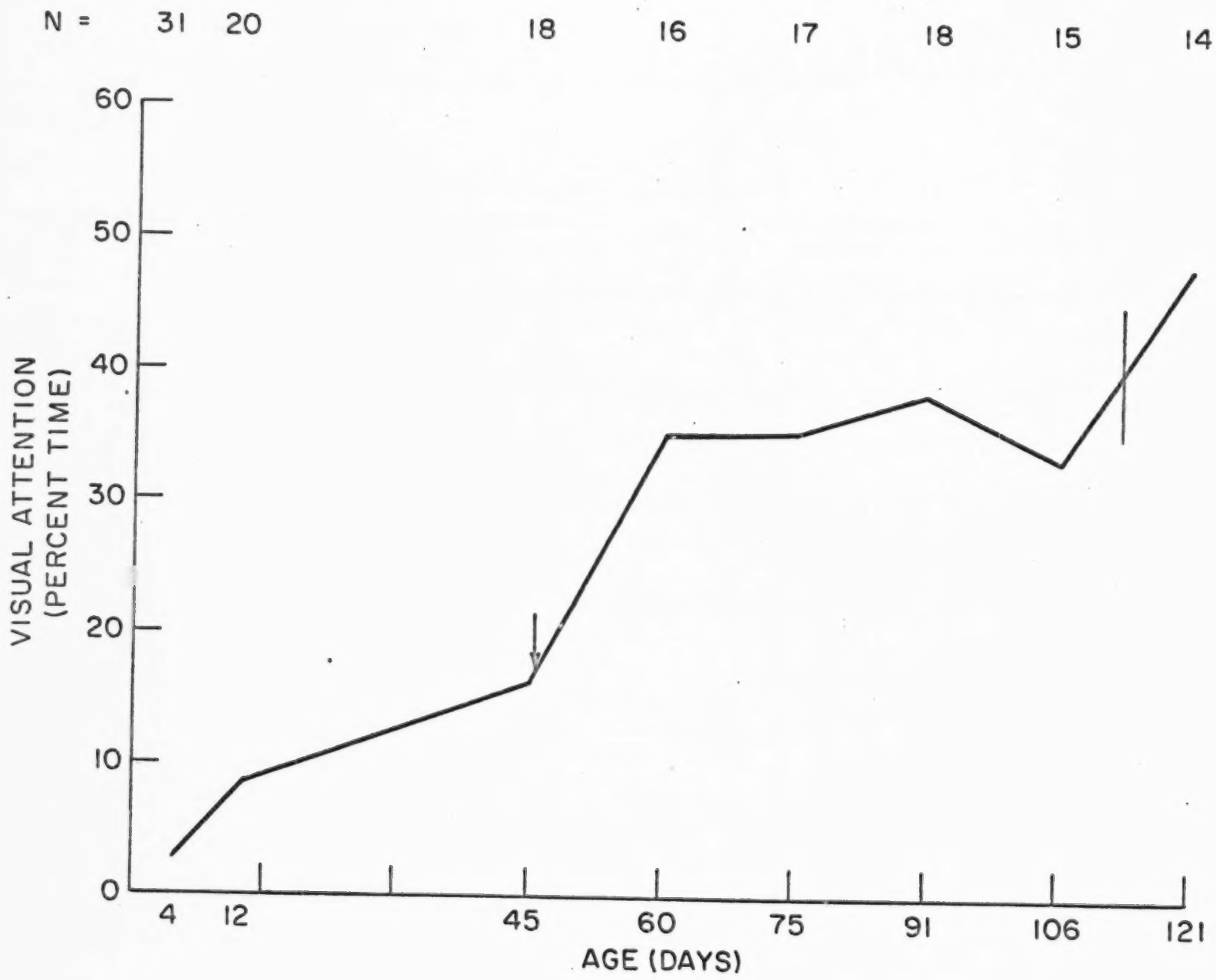
FIGURE 1

FIGURE 6

FIGURE 9



VISUAL ATTENTION DATA - CONTROL GROUP

FIGURE 2

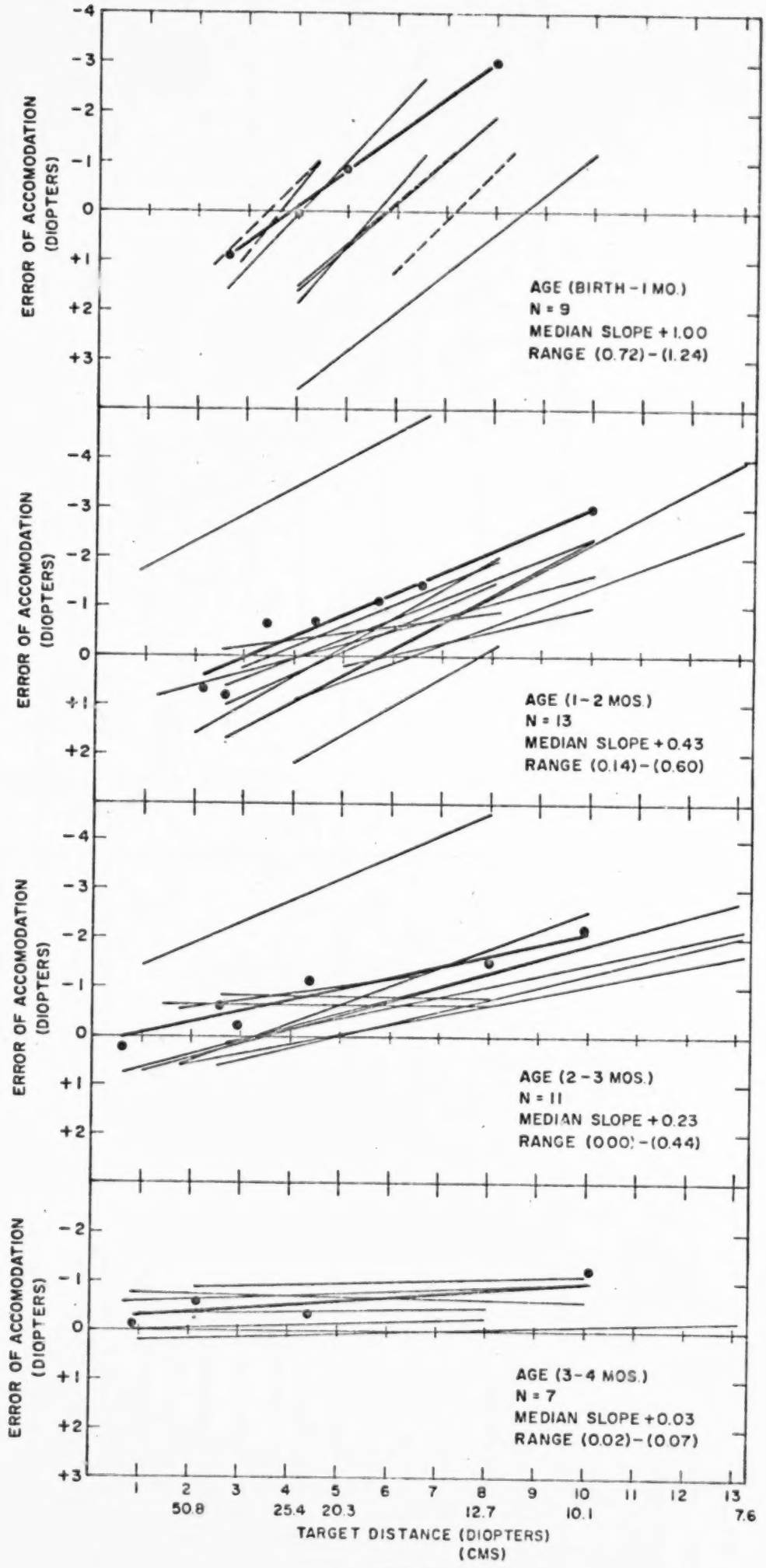

ERROR OF ACCOMODATION (DIOPTERS)
-4
-3
-2
-1
0
+1
+2
+3
AGE (BIRTH - 1 MO.)
N = 9
MEDIAN SLOPE + 1.00
RANGE (0.72) - (1.24)
AGE (1 - 2 MOS.)
N = 13
MEDIAN SLOPE + 0.43
RANGE (0.14) - (0.60)
AGE (2 - 3 MOS.)
N = 11
MEDIAN SLOPE + 0.23
RANGE (0.00) - (0.44)
AGE (3 - 4 MOS.)
N = 7
MEDIAN SLOPE + 0.03
RANGE (0.02) - (0.07)
1 2 3 4 5 6 7 8 9 10 11 12 13
50.8 25.4 20.3 12.7 10.1 7.6
TARGET DISTANCE (DIOPTERS)
(CMS)

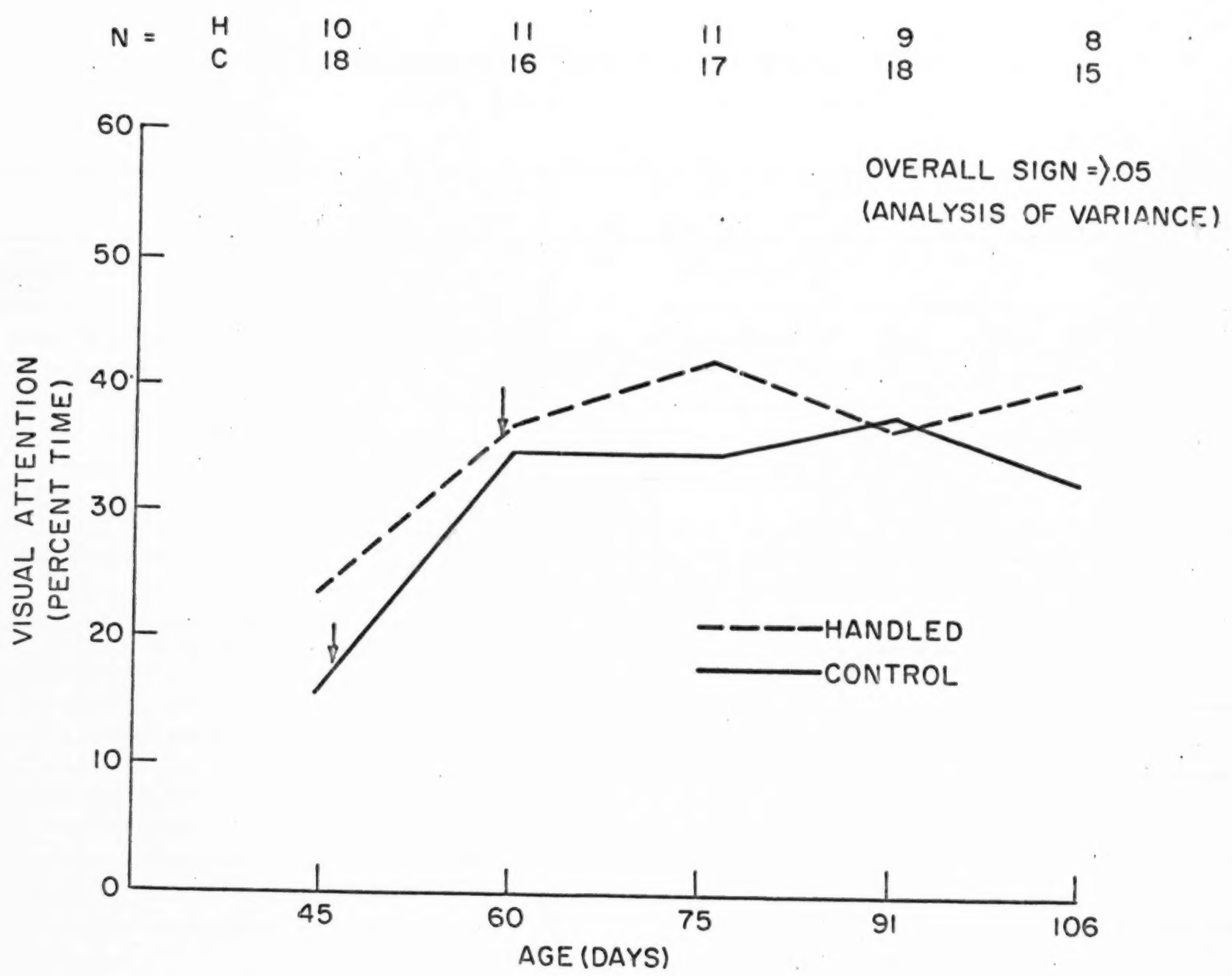
FIGURE 3

NORMATIVE DATA ON THE DEVELOPMENT OF VISUALLY-DIRECTED REACHING*

RESPONSE	OBSERVED IN	TOTAL N	MEDIAN AND RANGE OF DATES OF FIRST OCCURRENCE (DAYS) 20 40 60 80 100 120 140 160 180 200 220 240 260
SWIPES AT OBJECT	13	13	
UNILATERAL HAND RAISING	15	15	
BOTH HANDS RAISED	16	18	
ALTERNATING GLANCES (HAND AND OBJECT)	18	19	
HANDS TO MIDLINE AND CLASP	15	15	
ONE HAND RAISED WITH ALTERNATING GLANCES, OTHER HAND TO MIDLINE CLUTCHING DRESS	11	19	
TORSO ORIENTED TOWARDS OBJECT	15	18	
HANDS TO MIDLINE AND CLASP AND ORIENTED TOWARDS OBJECT	14	19	
PIAGET-TYPE REACH	12	18	
TOP LEVEL REACH	14	14	

* THESE DATA WERE COMPILED BY COMBINING THE SCORES OF CONTROL AND HANDLED INFANTS (WHICH DID NOT DIFFER SIGNIFICANTLY)

FIGURE 4



COMPARATIVE VISUAL ATTENTION DATA

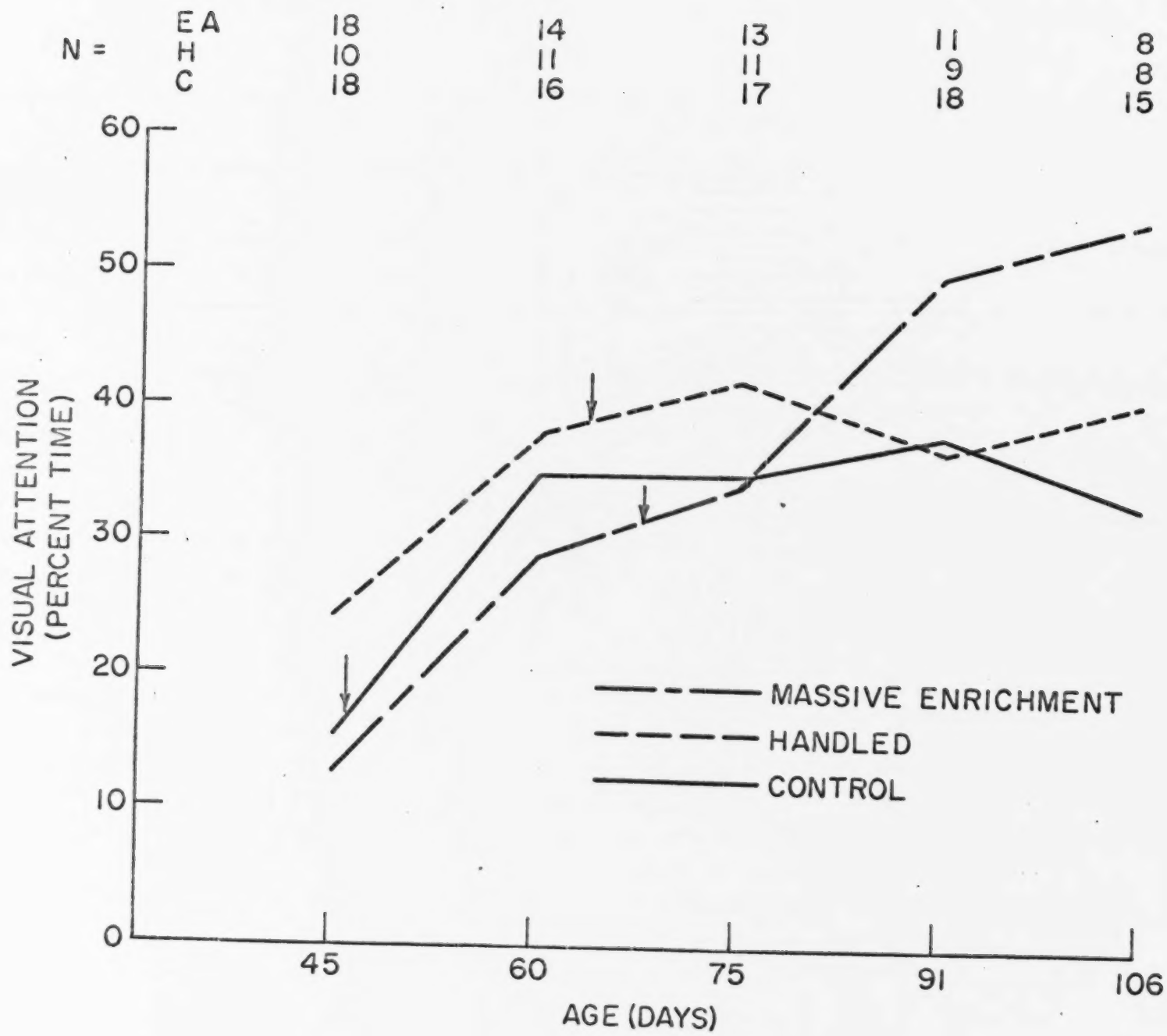
FIGURE 5

THE DEVELOPMENT OF VISUALLY-DIRECTED REACHING
STUDY B - MASSIVE ENRICHMENT

RESPONSE	OBSERVED IN	TOTAL N	MEDIAN AND RANGE OF DATES OF FIRST OCCURRENCE (DAYS) 20 40 60 80 100 120 140 160 180 200 220 240 260
SWIPES AT OBJECT	11	14	
UNILATERAL HAND RAISING	12	13	
BOTH HANDS RAISED	12	13	
ALTERNATING GLANCES (HAND AND OBJECT)	10	11	
HANDS TO MIDLINE AND CLASP	7	10	
ONE HAND RAISED WITH ALTERNATING GLANCES, OTHER HAND TO MIDLINE CLUTCHING DRESS	5	9	
TORSO ORIENTED TOWARDS OBJECT	4	9	
HANDS TO MIDLINE AND CLASP AND ORIENTED TOWARDS OBJECT	3	9	
PIAGET-TYPE REACH	6	9	
TOP LEVEL REACH	9	9	

PRECEDING PAGE MISSING

FIGURE 7

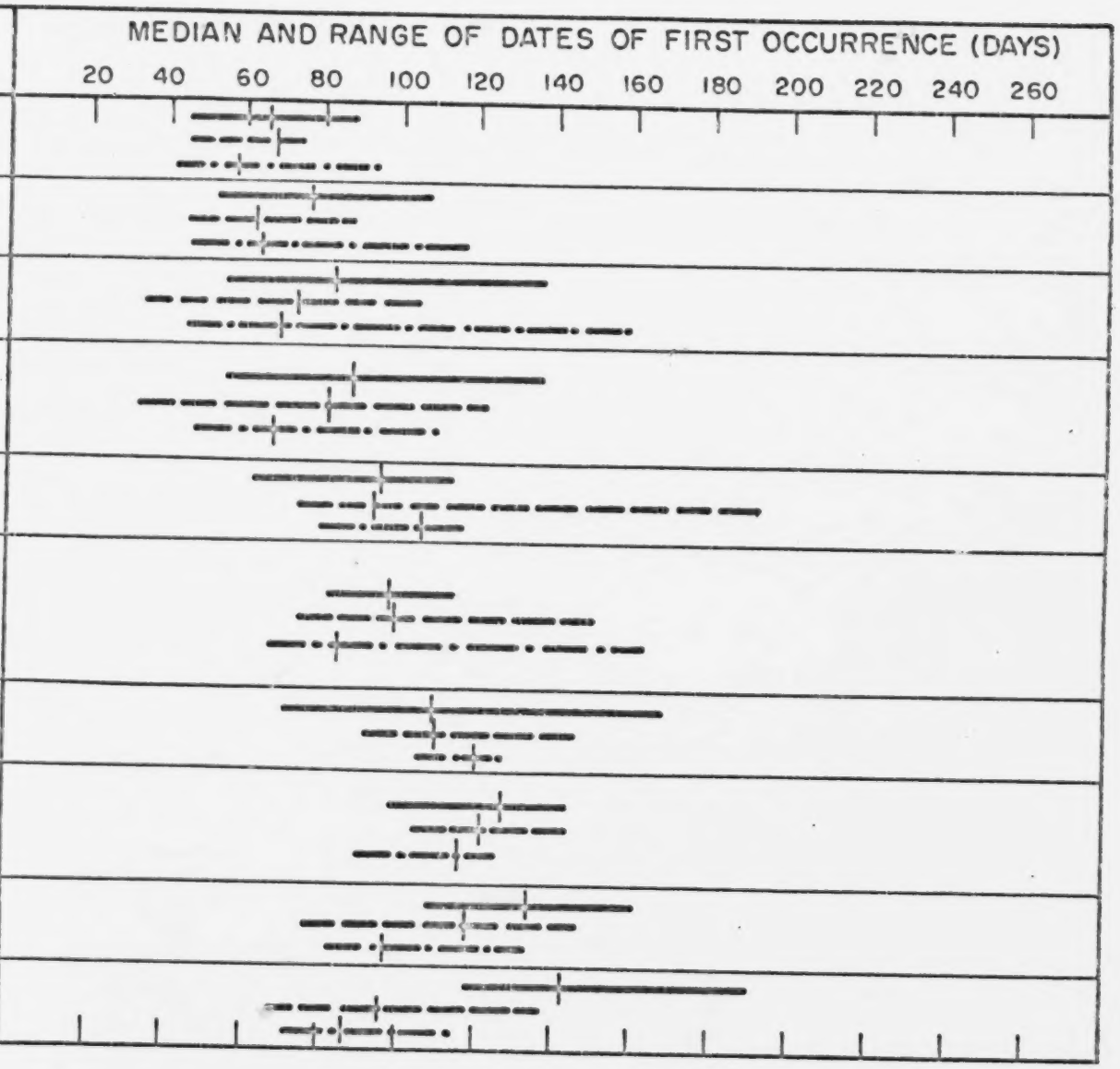


COMPARATIVE VISUAL ATTENTION DATA

FIGURE 8

COMPARISON OF PREHENSORY RESPONSES AMONG ALL GROUPS

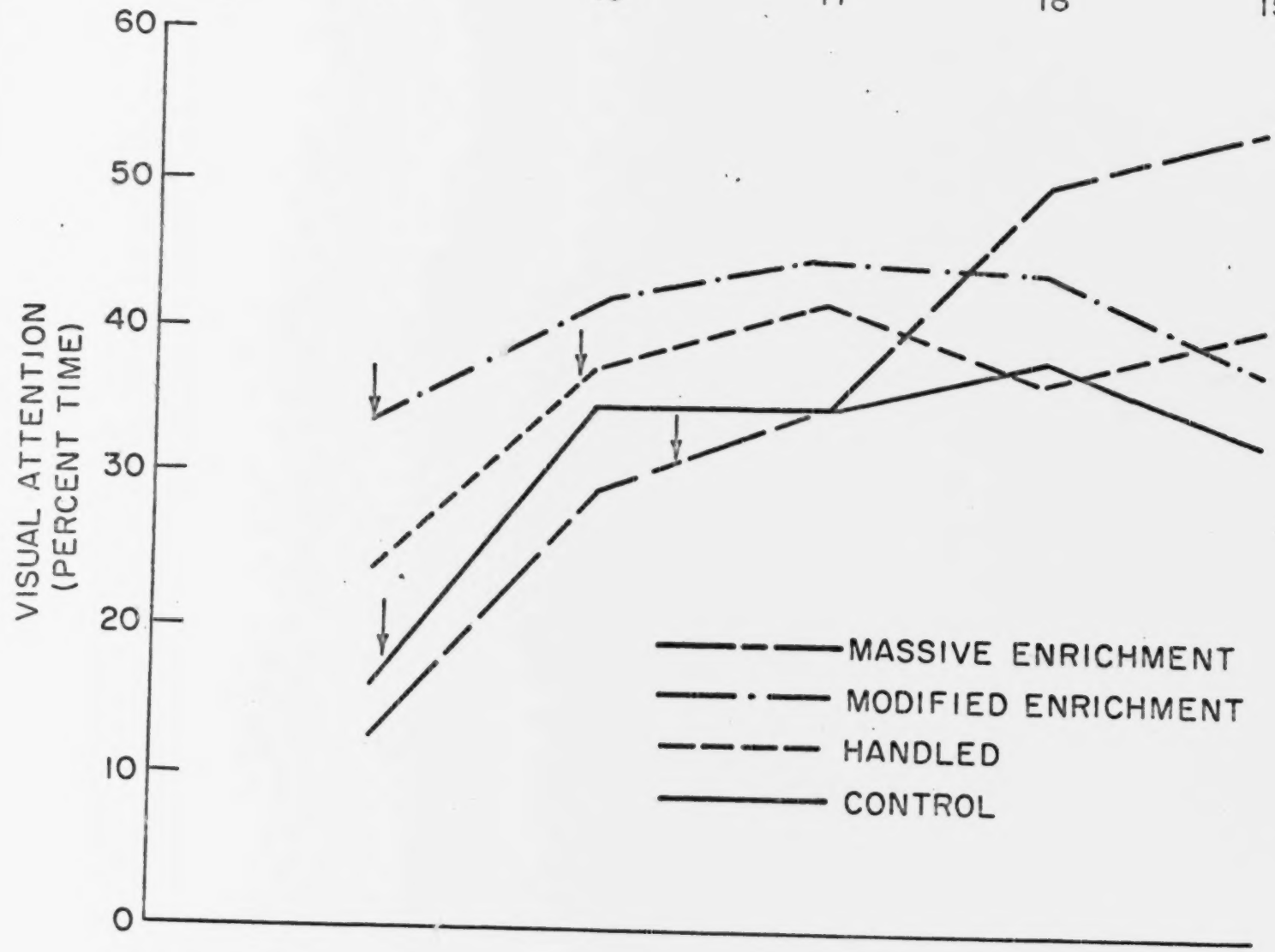
RESPONSE	OBSERVED IN	TOTAL N	MEDIAN AND RANGE OF DATES OF FIRST OCCURRENCE (DAYS)
SWIPES AT OBJECT	13 11 14	13 14 16	
UNILATERAL HAND RAISING	15 12 13	15 13 16	
BOTH HANDS RAISED	16 12 13	18 13 16	
ALTERNATING GLANCES (HAND AND OBJECT)	18 10 12	19 10 14	
HANDS TO MIDLINE AND CLASP	15 7 10	15 10 14	
ONE HAND RAISED WITH ALTERNATING GLANCES, OTHER HAND TO MIDLINE CLUTCHING DRESS	11 5 7	19 9 14	
TORSO ORIENTED TOWARDS OBJECT	15 4 5	18 9 12	
HANDS TO MIDLINE AND CLASP AND ORIENTED TOWARDS OBJECT	14 3 4	19 9 12	
PIAGET-TYPE REACH	12 6 8	18 9 13	
TOP LEVEL REACH	14 9 13	14 9 13	



PRECEDING PAGE MISSING

FIGURE 10

N =						
	EA	18	14	13	11	8
	EB	17	14	13	12	12
	H	10	11	11	9	8
	C	18	16	17	18	15



COMPARATIVE VISUAL ATTENTION DATA

FIGURE 11